Section 4:

Review of System Test Results and Future Test Plans

The system tests described in the following pages are intended to demonstrate the following:

- Low power transmitters used in the AP system design can deliver a reliable signal to the network of digital receivers the system will utilize.
- The proprietary receiver previously discussed will allow reliable data transmission in a high noise environment with high power adjacent channel interference.

The test program involves a series of field and laboratory tests. Our test program is presented in chronological order on the following pages. Field test one is completed, the remaining field tests and laboratory experiments will be completed using a recently granted experimental license no later than September 1, 1992.

Field Test #1

Experimental Goal:

Establish a baseline of Real World RF coverage to be expected with remotely transmitted intelligence from a low-powered (1.0 Watt) portable transmitter utilizing AFSK (Audio Frequency Shift Keying) emission utilizing a standard receiver which does not have "digiCEIVER" augmented reception. This field test will be utilized to determine the ability of a low-powered transmitter to operate within a radius of three Statute (3) miles or less of a fixed point receiver. Results obtained in this field test will be compared against results obtained in the subsequent field tests which will utilize FSK emission and receivers equipped with and without "digiCEIVER" augmented reception.

Experimental Setup:

A *commercially-available, battery-operated, low-power, portable* RF *transmitter* capable of producing AFSK FM modulation in the 450 MHz band is used to produce a coherent intelligence on the carrier. The intelligence so transmitted is generated by a commercially-available, battery-operated portable RF Modem which automatically generates data "beacon" consisting of a 1200 baud packet data burst in AX.25 Protocol transmitted at a ten (10) second interval.

At a fixed location, an identical Model/Transmitter unit is connected to an antenna and personal computer. This unit is primarily utilized as a receiving station. The personal computer is interfaced with the RF Modem. As the data is received from the mobile/portable unit it is decoded and "time stamped". The remotely transmitted data is simultaneously displayed on the personal computer screen and stored on disk.

The portable unit is transported over a previously determined route within a geographical area that does not exceed three (3) Statute Miles from the fixed point receiver. A computer model of expected RF signal strength is generated and utilized as a guide for locating projected weak signal or no signal areas within the test area.

The individual transporting the portable unit is equipped with a two-way radio unit or cellular telephone to communicate with the fixed location receiver operator.

Should the operator at the fixed point notice that a line of data is not displayed on the PC display within the ten (10) second "beacon" interval from the portable unit, a call via two-way or cellular is initiated to the individual transporting the portable unit to determine their location. A notation is then made indicating the location from which data is not being received.

At the conclusion of the coverage tests, a map overlay is generated indicating at what locations along the route taken by the carrier of the portable unit that signals were not received.

Experimental Test Result: Conducted April, 1992

Field Test #1 has been performed with satisfactory results thus proving the feasibility of a low-powered portable transmitter to send AFSK data while operating within a three (3) Statute Mile radius of a fixed-point non-augmented receiver. Readily obtainable "off-the-shelf" items of equipment were utilized in the performance of this test.

Laboratory Test #1:

Experimental Setup:

A modified RF transmitter capable of producing FSK FM modulation in the 900 MHz band is used to produce a coherent intelligence on the carrier. Said intelligence is a bit stream generated by a personal computer running a standard BERT/BLRT error analysis protocol. A second modified RF transmitter identical to the first is used to produce an interfering carrier offset by standard channel frequency spacing from the intelligent carrier and producing unit normal power. A standard receiver modified to produce RS-232c output will baseline the digiCEIVER's performance.

Experimental Goal:

Establish quantitative advantage of digiCEIVER augmented reception in the presence of unit normal strength narrow band interference.

Laboratory test #2:

Experimental Setup:

Identical to test #1 except for presence of passive attenuator in the RF output line of the signal transmitter. The attenuator allows a simulation of increased distance between the transmitter and the receiver while the interfering carrier's power level is increased above unit normal level relative to the intelligent signal.

Experimental Goal:

Establish quantitative advantage of digiCEIVER augmented reception over a conventional receiver in the presence of strong interference and simulated distance.

Laboratory Test #3:

Experimental Setup:

Identical to test #1 except for presence of passive attenuator in the RF output line of the interfering transmitter. The interfering transmitter is tuned to produce interfering RF on the same frequency as the intelligent carrier. The attenuator serves to reduce the power level of the interfering carrier to a fraction of unit normal output power.

Experimental Goal:

Establish the quantitative advantage of the digiCEIVER in the presence of on channel interference.

All experiments are to be conducted in a laboratory environment. After the data has been analyzed then a similar series of real world experiments will be outlined and performed.

Field Test #2:

Experimental Goal:

Establish a baseline of Real World RF coverage to be expected with remotely transmitted intelligence from a low-powered (1.0 Watt) portable transmitter utilizing FSK (Frequency Shift Keying) emission utilizing a standard receiver which does not have "digiCEIVER" augmented reception. Results obtained in this field test will be compared against results obtained in the subsequent field test which will utilize a receiver with "digiCEIVER" augmented reception, thus giving determining the quantitative advantage "digiCEIVER" augmented reception.

Experimental Setup:

A commercially-available, battery-operated, low-power, portable RF Transmitter capable of producing FSK FM Modulation in the 900 MHz band is used to produce a coherent intelligence on the carrier. The intelligence so transmitted is generated by a commercially-available battery-operated portable RF modem which automatically generates data "beacon" consisting of 1200 baud packet data burst in AX.25 Protocol transmitted at ten (10) second interval.

At a fixed location, an identical Model/Transmitter unit is connected to an antenna and personal computer. This unit is primarily utilized as a receiving station. The personal computer is interfaced with the RF modem. As the data is received from the mobile/portable unit it is decoded and "time stamped". The remotely transmitted data is simultaneously displayed on the personal computer screen and stored on disk.

The portable unit is transported over a previously determined route within a geographical area that does not exceed three (3) Statute Miles from the fixed point receiver. A computer model of expected RF signal strength is generated and utilized as a guide for locating projected weak signal or no signal areas within the test area.

The individual transporting the portable unit is equipped with a two-way radio unit or cellular telephone to communicate with the fixed location receiver operator.

Should the operator at the fixed point notice that a line of data is not displayed on the PC display within the ten (10) second "beacon" interval from the portable unit, a call via two-way or cellular is initiated to the individual transporting the portable unit to determine their location. A notation is then made indicating the location from which data is not being received.

At the conclusion of the coverage tests, a map overlay is generated indicating at what locations along the route taken by the carrier of the portable unit that signals were not received.

Field Test #3:

Experimental Goal:

To compare the baseline of Real World RF coverage obtained in Field Test #2 and establish the Quantitative Advantage of "digiCEIVER" augmented reception.

Experimental Setup:

Setup and conduct of this test will be identical to Field Test #2 with the exception of the fixed receiver being of the "digiCEIVER" augmented configuration.

Field Test #4:

Experimental Goal:

To compare the baseline of Real World RF coverage obtained in Field Test #2 and establish the Quantitative Advantage of "digiCEIVER" augmented reception in the presence of on-frequency (co-channel) interference.

Experimental Setup:

Setup and conduct of this test will be identical to Field Test #2 with the exception of the fixed receiver being of the "digiCEIVER" augmented configuration. A 900 MHz FSK transmitter utilizing 1000 Watts Effective Radiated Power (ERP) on the same frequency as the portable unit will be utilized to generate interference.

Field Test #5:

Experimental Goal:

To compare the baseline of Real World RF coverage obtained in Field Test #2 and establish the Quantitative Advantage of "digiCEIVER" augmented reception in the presence of adjacent channel interference.

Experimental Setup:

Setup and conduct of this test will be identical to Field Test #2 with the exception of the fixed receiver being of the "digiCEIVER" augmented configuration. A 900 MHz FSK transmitter utilizing 1000 Watts Effective Radiated Power (ERP) on a frequency separated by 25 KHz from the frequency of the portable unit will be utilized to generate interference. Subsequent identical tests will be performed with the interference transmitter operating on frequencies separated by 50 KHz, 75 KHz and 100 KHz.

Exhibit 1

A DYNAMICALLY RECURSIVE DIGITAL DISCRIMINATOR FOR THE DEMODULATION OF MONOTONIC BIPHASE FM RADIO SIGNALLING

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Abstract:

The explication of a Digital Signal Processing Assembly for the detection and demodulation of FSK modulated narrow band carriers is outlined with emphasis on some of the more novel digital innovations. The use of sub-Nyquist sampling, auto-recursive FIR filtering techniques, and ganged digital amplifiers and attenuators is discussed. The application of the unit to long distance telemetry is detailed.

This product has direct application for any process requiring extremely precise tone decoding or detection of a weak signal in a noisy environment. Acknowledgement Paging, RF telemetry, and information transfer, are all key uses for such a product.

Introduction:

The use of direct Frequency Shift Keying as a method of narrow band carrier modulation has been increasing steadily since the early 1980's. Its prevalence as a medium for telemetric signalling and general intelligence transmission stems in large measure from the ease with which it may be demodulated and converted to a standard data protocol (i.e.: RS232c, etc.) Unfortunately as FSK's use has increased the spectrum allocated for its use has just as steadily decreased. The end result being that co-channel interference has become a serious threat to once reliable reception. The inability of a conventional discriminator or detector to achieve capture of a signal with less than 4:1 relative signal strength ratio is becoming a serious barrier to reliable communication, particularly from weak sources.

With the advent of high speed Analog to Digital converters and VLSI implementation of DSP assemblies it is now possible to circumvent some of the aforementioned limitations and increase the reliable capture range several fold. In order to obtain the maximum benefit from utilizing DSP much of the conventional analog receiver circuitry must be replaced with digital assemblies.

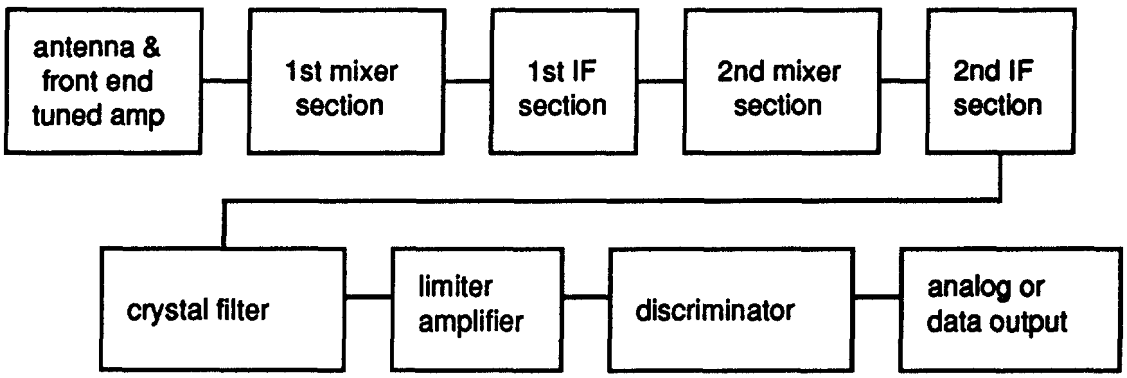

FIGURE 1
the conventional receiver

As seen in Figure 1, there are several basic subsystems integrated in the receiver. We will be concerned with augmenting the front end and AGC and replacing the limiter amplifier and discriminator with digital components.

Front End and AGC:

It is necessary to insure that the front end of the receiver is not susceptible to input saturation by proximate out-band or in-band carriers. this may be accomplished through the use of a digitally programmable attenuator placed ahead of the front end. A flash A/D converter (6 bit range) samples the 10.7 MHz

IF and drives the digital attenuator. In addition, the ADC controls a switch tree RF amplifier network.

It is important to have a fast AGC because saturation and clipping cause a loss of low level signal information. The front end signal is a superpositive sum of all of the signals with the bandwidth of the tuned amplifier. A conventional AGC will tend to average the input level and then overshoot the attenuation. It does too much, too late. Replacing it with a flash ADC whose Nyquist rate is in excess of the 2nd IF frequency is a more than adequate solution.

The Limiter:

In a conventional receiver the limiter amplifier does double duty as the principle gain stage in the receiver as well as being the "capture" element in the signal processing chain. A gain factor of 100 dB is not uncommon for the limiter amp. It saturates by design and so is unsuitable for our purposes. We replace the limiter block with a switched tree of linear amplifiers with an aggregate gain of 110 dB. The switched tree network is under the control of the digital AGC circuit. This allows for programmable gain matched to the input signal strength. The superpositive sum of in-band signals is left in tact by the linear switched tree gain block. This allows the full in-band spectrum to be input to the discriminator.

The Discriminator:

The conventional analog discriminator consists of a product detector and an out-of-resonance tuned circuit. It is unsuited for FSK detection.

The conventional FSK discriminator consists of a product detector and a biphase comparator circuit. For strong signals (>>4:1 RSS) in the absence of spurious in-band interference it works reasonably well. The conventional FSK discriminator assumes that any deviation above +3 KHz is a logical "1" or TRUE state and that any deviation below -3 KHz is a logical "0" or FALSE state. These assumptions are predicated on the belief that the limiter will saturate and "capture" the strongest signal and that the strongest signal is the one of interest. Should either of these assumptions prove false then the discriminator outputs garbage rather than data.

If we are looking for a weak signal in a congested spectrum then both assumptions are false. One way out of this dilemma is to narrow the bandwidth of the logical events. If we require a logical "1" to be represented by a deviation of +4.8 KHz +- 100 Hz and a logical "0" to be represented by -4.8 KHz +- 100 Hz then they may be distinguished even in a sea of wide and narrow band noise; provided the narrow band noise does not fall within the passband of the information signal.

Unfortunately the parameters stated above require a bandpass circuit with a Q of 200. While such a circuit could be synthesized with analog components it would be unsatisfactory to the task at hand. An active filter with a Q of 200 will ring like a bell and its decay rate is longer than the bit rate for all but the slowest (<110 baud) transmission speeds. A Phase Lock Loop can achieve a Q of 200 but it requires a S/n >> 8 to achieve lock within a moderate time. A Caur or elliptical filter could be constructed but the critical components values and Tempco would destabilize it from the outset.

It is possible, however; to achieve these performance specifications utilizing a parallel DSP architecture with a high speed sampling ADC.

We utilize a high speed ADC to undersample the output of the 10.7 MHz IF. Sub-Nyquist sampling is possible because FSK modulation is actually biphase monotonic AM. With a bank-limited excursion of 5 KHz it is possible to sample at 20 KHz and dispense with a third mixer <u>even though the Nyquist rate is in excess of 200 times the sample rate</u>.

We parallel two ADSP2101 DSP microcomputers under the control of an 80c186 microcomputer. The 2101's do the convolution sum required to implement a 540 tap FIR bandpass filter. This provides a filter with a <u>Q > 250 that does not ring or require any precision components</u>.

After the input data is filtered and stored the 2101's are dynamically reconfigured to be a recursive lock-in amplifier. In this mode they can locate a -50 dB signal with +25 dB of spurious noise. This is a dynamic range of <u>75 dB</u>.

The data is then made available for output as asynchronous RS232.

This product has direct application for any process requiring extremely precise tone decoding or detection of a weak signal in a noisy environment. Acknowledgement Paging RF telemetry, information transfer, etc. are all ripe with uses for such a product.

CERTIFICATE OF SERVICE

I, Patricia Edwards, a secretary in the law offices of Lukas, McGowan, Nace & Gutierrez, Chartered, do hereby certify that I have on the 1st day of June, 1992, sent by first class United States mail copies of the foregoing SUPPLEMENT TO PETITION FOR RULEMAKING to the following:

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Attachment A

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